(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 468 728 A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 91306665.0

(51) Int. Cl.^{5}: G06F 15/21

(22) Date of filing: 22.07.91

(30) Priority: 26.07.90 US 558970

(43) Date of publication of application: 29.01.92 Bulletin 92/05

(84) Designated Contracting States: DE FR GB IT NL

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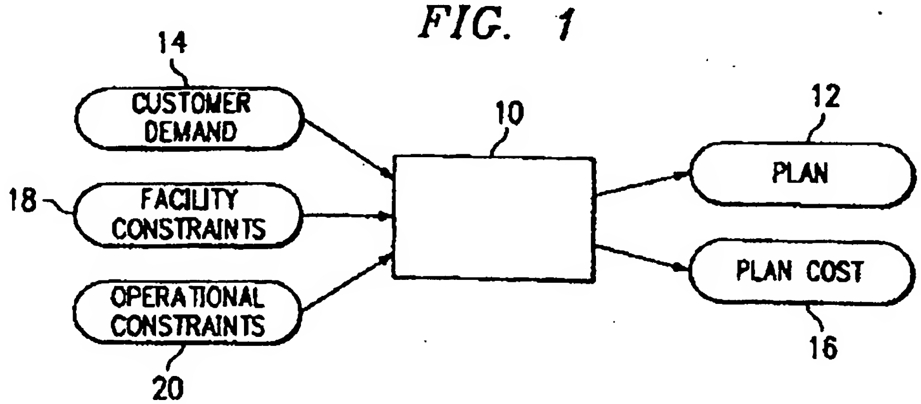
(54) Apparatus and method for production planning.

(57) Apparatus for production planning in a manufacturing facility is provided. The apparatus comprises means (10) for generating a plurality of theoretical plans and a constraint-based model for receiving one of the theoretical production plans, and applying at least one constraint (18, 20) thereto. Further, a cost function (16) is computed for the theoretical production plans. Means is then provided for searching for a feasible production plan among the plurality of theoretical plans, where the feasible plan is the plan which does not violate the applied constraint and has the least computed cost function.

FIG. 1



EP 0 468 728 A2

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TECHNICAL FIELD OF THE INVENTION

This invention relates in general to the field of scheduling systems. More particularly, the present invention relates to apparatus and a method for production planning.

BACKGROUND OF THE INVENTION

Production planning is the process of choosing work to be started in a manufacturing facility during some future time period so that performance is maximized. Work is usually selected from a variety of product types which may require different resources and serve different customers. Therefore, the selection must optimize customer-independent performance measures such as cycle time and customer-dependent performance measures such as on-time delivery.

The reasons for requiring advanced production planning may be unique to each manufacturing facility. For example, one facility may require advanced planning so that materials may be ordered and delivered in time for manufacture. Another facility may require advanced planning in order to make delivery commitments or predict delays in product delivery.

In order to configure a production plan which yields the best performance, the capacity, or the amount of work the facility can handle, must be modeled in some fashion, since starting work above the capacity of the facility compromises performance and brings forth no benefits. Conventional factory capacity models employ simple steady-state linear relations that include: (1) the average amount of available work time for each machine in the factory and (2) the amount of work each product requires of each machine. From the above linear relations, a given start plan is within capacity if, for each machine, the total required amount of work is: (1) less than the machine's available time, and (2) multiplied by a predetermined fraction goal utilization of the start rate.

There are several problems associated with a linear production planning program. Because of the large problem size, variables in linear programs must be expressed in non-integer quantities in order to yield good solutions. As a result, fractional start quantities may be generated which must be converted into discrete start quantities. Such forced conversion sacrifices the goodness of the solution.

Additionally, non-linear relationships cannot be modeled in a linear program. Examples of such relationships are the expected yield for a product's start quantity, and the cost of surplus and delinquency. Such non-linear relationships have been traditionally coerced into linear expressions with loss of precision.

The large problem size presents another obstacle for linear production planning programs. Even if a planning problem can be expressed in a linear program, the problem size may prohibit efficient solution via conventional linear programming techniques. This problem has not been overcome in the industry without substantial loss of optimality in the solution.

Therefore, a need has arisen for apparatus and method to formulate a production plan for a manufacturing facility that accommodates integer variables, allows non-linear expressions and provides a near optimal production plan despite the large problem size.

SUMMARY OF THE INVENTION

In accordance with the present invention, apparatus and method for production planning are provided which substantially eliminate or reduce disadvantages and problems associated with prior production planners.

In one aspect of the present invention, apparatus for production planning in a manufacturing facility is provided. The apparatus comprises means for generating a plurality of theoretical plans and a constraint-based model for evaluating one of the theoretical production plans, and applying at least one constraint thereto. Further, a cost function is computed for each of the theoretical production plans. Means is then provided for searching for a feasible production plan among the plurality of theoretical plans that does not violate any of the applied constraints and has the least computed cost function value.

In another aspect of the present invention, apparatus for production planning in a manufacturing facility is provided. The apparatus comprises means for computing the capacity of the factory in order to produce the determined quantities and types of product, means for computing the maximum factory capacity, and means for comparing the computed production capacity with the maximum factory capacity. Further included are means for computing the cost of producing the determined quantities and types of product in response to the computed production capacity being less than or equal to the maximum factory capacity and means for selecting a production plan that has the least computed cost function value.

In yet another aspect of the present invention, a method for generating a production plan for a manufacturing facility is provided, which comprises the steps of initializing the production plan, and generating a plurality

of proposals to modify the production plan. At least one constraint is formulated and applied to the production plan as modified by each of the plurality of proposals. Any proposal which causes the production plan to contradict the constraints is then discarded, after which the cost of implementing the production plan as modified by each of the remaining proposals is computed. A proposal which causes the production plan to have the least computed cost is selected and the above steps are repeated until no proposals remain after the discarding step. The current production plan is then offered as the solution production plan.

An important technical advantage of the present invention provides a formulation of production planning as a cost minimization problem using constraint-based models.

Another important technical advantage of the present invention provides a production planner which employs a heuristic search algorithm which iteratively manipulates a starting plan to reduce the plan cost until no further manipulation improves the plan.

Yet another important technical advantage of the present invention provides a more accurate production planner which accommodates real variables and linear equalities as well as integer variables and non-linear equalities.

BRIEF DESCRIPTION OF THY DRAWINGS

For a better understanding of the present invention, reference may be made to the accompanying drawings, in which:

FIG. 1 is a simplified block diagramm showing the inputs and outputs of the present invention;

FIG. 2 is a flowchart of a heuristic search algorithm in the preferred embodiment of the present invention; and

FIG. 3 is a constraint flow diagram illustrating a planning model in the preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

With reference to the drawings, FIG. 1 illustrates some of the input and output parameters of a preferred embodiment of the apparatus and method for production planning for a manufacturing facility, indicated generally at 10 and constructed according to the teaching of the present invention. In order to formulate a production plan 12, production planner 10 takes into consideration inputs such as customer demand 14. Customer demand 14 may specify the quantity and type of products ordered by the customer, and the delivery date of the order. Customer demands 14 may also be prioritized in the order of importance. The output or end product of the manufacturing facility, when produced in accordance with production plan 12, should preferably meet customer demand 14 and yet not result in an over abundance in inventory. Similarly, there is also penalty when customer demand 14 is not met by the production plan 12. Therefore, associated with each production plan 12 is a plan cost 16, which represents the cost of implementing the plan.

Another set of inputs 18 describes the constraints placed on production planner 10 from facility related parameters, such as machine capacity, down time, etc. Therefore, the production volume is checked by facility constraints 18. Additional constraints 20 arising from the operation of the facility, such as yield, surplus and work-in-process, also regulate the production quantity and type of product that should be started.

Referring to FIG. 2, a flowchart 30 of a heuristic search algorithm of the preferred embodiment of the present invention 10 is shown. The present invention employs the heuristic search algorithm to search for a suitable plan which specifies the product type and quantity to be started at the beginning of the next planning period without incurring high cost or violating any facility or operational constraints 18 and 20. The search algorithm starts by setting the quantities for all product types to zero. For a semiconductor wafer fabrication facility, this equates to setting the number of lots to be started to zero for all device types. This results in the worst and highest cost plan, since by producing nothing, none of the customer demands will be met.

From the initial zero plan, a set of operators which proposes changes to the plan is generated, as shown in block 34. The operators may propose to modify the plan in two ways. They may increase the number of lots to be started by one for a particular device type, or they may set the number of lots to a determinable number, so that critical customer orders for each device are covered. All operators reachable from the current plan in the above-identified ways are generated and examined to determine their feasibility. Those operators which generate plans that contradict facility or operational constraints are eliminated from the search, as shown in block 36.

If there are remaining operators, as determined in decision block 38, then a plan cost is computed for each remaining proposed plan. Of the remaining operators, the one which yields the most decrease in computed plan cost per addition to work is selected, as shown in block 44. The change in work may be defined as the

```
EXPECTED_SURPLUS(PRODUCT) =
      MAX(0,AVG_OUTPUT(STARTS(PRODUCT)) -
      TOTAL_DEMAND(PRODUCT), and

If STARTS(PRODUCT) > 0 then
      EXPECTED_SURPLUS(PRODUCT)/TOTAL_DEMAND(PRODUCT)
      µ MAX_SURPLUS_DEMAND_RATIO.
```

EXPECTED_SURPLUS(PRODUCT) is the expected surplus for each product; AVG_OUTPUT(STARTS(PRODUCT)) equals to STARTS(PRODUCT) * AVG_YIELD(PRODUCT); TOTAL_DEMAND(PRODUCT) is the amount of all known demands for each product, including non-startable demands; and MAX_SURPLUS DEMAND_RATIO is an input parameter predetermined by facility personnel.

From the foregoing, it may be seen that surplus feasibility constraint 73 states that if the lot-start number is positive for a product, surplus is acceptable if the ratio of expected surplus to total demand (computed from customer demand 74) does not exceed MAX_SURPLUS_DEMAND_RATIO.

A facility may choose to accommodate partial lots which contain a fewer number of wafers than a full lot. Partial lots are useful to meet small customer demands, but tend to utilize certain machines poorly, such as batch machines like ovens. Therefore, in order to ensure good facility utilization, a partial lot feasibility constraint 75 is applied to the number of starting lots 50. From the number of starting lots for each product 51-53, the number of partial lots 76 and full lots 77 are computed by partial lot count and full lot count constraints 78 and 79, respectively. Partial lot feasibility constraint 75 may be expressed by the following:

If NUM_FULL_LOTS > 0 then
NUM_PART LOTS/NUM_FULL_LOTS µ MAX_PART_LOT_RATIO,

where MAX_PART_LOT_RATIO is an input parameter determined by facility personnel.

Returning to block 36 in FIG. 2, it may be seen that the above-described capacity, surplus feasibility, and partial lot feasibility constraints are applied to the plan modification proposed by each operator, and those operators which contradict the constraints are removed from the search. It is important to note that although specific constraints are shown herein, they merely serve as examples of how constraints may be used in the present invention to compute a production plan. Therefore, other constraints known in the art may be applicable to the present invention and are within the scope thereof.

In block 42, those remaining operators are applied to the current plan to compute the cost of the modified plan. This computation is shown in FIG. 3. The number of lots to be started for each product type 51-53 are subject to a yield constraint to compute an expected yield 81 for each device type 82-84. In the preferred embodiment of the present invention, yield constraint 80 may be expressed by the following statistical formula:

YIELD(PRODUCT) =
AVG-YIELD(PRODUCT) * START(PRODUCT) -
VARIANCE(PRODUCT) * SQRT(START(PRODUCT)) * K

The average yield and variance of each product, AVG_YIELD(PRODUCT) and VARIANCE(PRODUCT), are computed from previous yield values. If desired, trend analysis and other methods to achieve better yield prediction may also be used. K is an input parameter specifying a measure of confidence in the chance that at least YIELD will be produced from START for each product type. From the foregoing, it may be recognized that higher K or confidence results in production of sufficient quantity to more frequently meet customer demand. However, more inventory may be produced, since more lots are started per demand.

Expected yield for each device type 82-84 is subject to demand constraints 85 and pull-ahead constraints 86 to compute push cost and pull cost per device 87 and 88, respectively. Push cost 87 is defined as the cost of not covering customer demand and pull cost 88 is defined as the cost of producing orders ahead of time. Therefore, demand constraints 85 and pull-ahead constraints receive input from customer demand 74. There are known formulas for computing the push and pull costs, and will not be discussed further herein.

The push cost per device 89-91 and pull cost per device 92-94 are summed independently by summation constraints 95 and 96 to calculate for the total push cost 97 and total pull cost 98 of the plan. The total push and pull costs 97 and 98 are summed again by a third summation constraint 99 to yield the total cost 100 of the plan.

As mentioned above, the total plan cost 100 provides a measure of the goodness of the plan. If an operator proposes a plan that costs the least and adds the least amount of work among all remaining operators and

yields no feasible children operators in the search tree, then the plan proposed by the operator is the solution plan.

Preferred embodiment Features

Various important features of the preferred embodiment are summarized below.

An apparatus for production planning in a manufacturing facility, where the facility manufactures quantities of at least one type of product to meet customer demand, the apparatus including means for determining a production plan including the quantities and types of product to be produced, means for producing the capacity of the factory in order to produce the determined quantities and types of product, means for computing the maximum factory capacity, means for comparing the computed production capacity with the maximum factory capacity, means for computing the cost of producing the determined quantities and types of product per addition to work in response to the computed production capacity being less than or equal to the maximum factory capacity, and means for selecting a production plan that incurs the least cost per addition to work. Such an apparatus may also include means for receiving the quantities and types of product demanded by customers, as well as means for computing a surplus feasibility constraint that describes the quantities and types of product which are expected to yield large surpluses when compared to the customer demand. Furthermore, this cost computing means computes production cost in response to the determined quantities and types of product not generating large surpluses as compared with the surplus feasibility constraint. The capacity computing means may further include means for modeling the machine capacity in the manufacturing facility and means for computing machine usage required for the quantities and types of product using the machine capacity model. Additionally, the capacity computing means may further comprise means for storing and supplying machine availability data, means for storing and supplying the number of work hours of the manufacturing facility, means for computing the work-in-process workload, and means for computing the maximum usage per machine in response to the machine availability data, number of work hours, and work-in-process workload. The cost computing means may also comprise means for computing the push cost incurred by not producing enough quantities to meet the customer demand, as well as means for computing the pull cost incurred by producing ahead of schedule delivery time. Such cost computing means may also comprise means for summing the push and pull cost to determine a total plan cost. Moreover, the above production planning apparatus, wherein the manufacturing facility produces units of a predetermined quantity of product and partial units of another predetermined quantity of product, may further include means for computing the number of units of each product to be produced, means for computing the number of partial units of each product to be produced, means for determining the feasibility of producing the computed number of units and partial units, and the cost computing means computing the cost in response to producing the computed number of units and partial units being feasible.

A method for generating a production plan for a manufacturing facility, includes the steps of initializing the production plan, generating a plurality of proposals to modify the production plan, formulating at least one constraint, applying the at least one constraint to the production plan as modified by each of the plurality of proposals, discarding any proposal which causes the production plan to contradict the constraints, computing the cost of implementing the production plan as modified by each of the remaining proposals, selecting a proposal which causes the production plan to have the least computed cost, repeating all of these steps until no proposals remain after the discarding step, and providing the current production plan as a solution production plan. The constraint formulating and applying steps may include the steps of formulating and applying a production capacity constraint of the manufacturing facility to the theoretical plan, where the manufacturing facility may have at least one machine and wherein the capacity constraint formulating step may further comprise the steps of storing and providing the availability of each machine, controlling the work-in-process workload, storing and providing the number of work hours of the manufacturing facility, and receiving the machine availability, work-in-process and work hours and computing the maximum amount of usage of machine. Additionally, the capacity constraint formulating step may include the steps of storing and providing the amount of usage per machine, and receiving the machine usage and computing the amount of current usage per machine in response thereto. Such capacity constraint formulating step may additionally include the step of formulating the production capacity of the manufacturing facility in response to the maximum usage per machine and the current usage per machine. Moreover, the constraint formulating and applying steps may comprise the steps of formulating and applying a constraint which describes the amount of surplus that may be feasibly produced by the manufacturing facility, wherein the manufacturing facility produces at least one type of product, and wherein the surplus feasibility constraint formulating step may also comprise computing expected surplus per product type in response to the theoretical production plan as well as formulating the surplus feasibility constraint in response to the computed expected surplus. Furthermore, the manufacturing facility manufactures in units of a fixed num-

ber and also in partial units of a number less than the fixed number, wherein the constraint formulating and applying steps of the above-described method comprise the steps of formulating and applying a constraint which describes the number of partial production units that may be feasibly initiated by the manufacturing facility. The partial unit feasibility constraint formulating step may include the steps of computing the number of units that are required to be initiated in response to the theoretical production plan, computing the number of partial units that are required to be initiated in response to the theoretical production plan, and formulating the partial unit feasibility constraint in response to the computed number of units and partial units required for the theoretical production plan. Lastly, the manufacturing facility produces at least one type of product, wherein the cost function computing step may include the steps of computing an expected yield per product type, receiving customer demand, computing a push cost per product type in response to the computed expected yield and the received customer demand, computing a pull cost per product type in response to the computed expected yield and the received customer demand, and computing a cost function of the production plan in response to the computed push and pull costs.

Although the present invention has been described in the environment of a semiconductor wafer fabrication facility, the constraint-based model combined with the heuristic search algorithm as taught by the present invention is applicable to other production environments.

Furthermore, it should be understood that various changes, substitutions and alterations can be made hereto without departing from the spirit and scope of the present invention as defined by the appended claims.

Claims

1. Apparatus for production planning in a manufacturing facility, comprising:
   means for generating a plurality of theoretical plans;
   a constraint-based model for receiving one of said theoretical production plans, and applying at least one constraint thereto;
   means for computing a cost function per addition to work in response to said theoretical production plan; and heuristic means for searching for a feasible production plan among said plurality of theoretical plans, said feasible plan not violating said applied constraint and having the least computed cost function value per addition to work.

2. The apparatus, as set forth in claim 1, wherein said constraint-based model applies a plurality of constraints to each said theoretical production plan, and said feasible plan does not violate any of said plurality of constraints.

3. The apparatus, as set forth in claim 1, wherein said constraint-based model comprises means for applying a production capacity constraint of said manufacturing facility to said theoretical plan.

4. The apparatus, as set forth in claim 3, said manufacturing facility having at least one machine and wherein said capacity constraint applying means further includes:
   means for storing and providing the availability of each machine;
   means for controlling the amount of work-in-process;
   means for storing and providing the number of work hours of said manufacturing facility; and
   means for receiving said machine availability, work-in-process and work hours and computing the maximum amount of usage of said machine.

5. The apparatus, as set forth in claim 4, wherein said capacity constraint applying means includes:
   means for storing and providing the amount of usage per machine; and
   means for receiving said machine usage and computing the amount of current usage per machine in response thereto.

6. The apparatus, as set forth in claim 5, said capacity constraint applying means further comprises means for formulating said production capacity of said manufacturing facility in response to said maximum usage per machine and said current usage per machine.

7. The apparatus, as set forth in claim 1, wherein said constraint-based model comprises means for applying a constraint which describes the amount of surplus that may be feasibly produced by said manufacturing facility.

8. The apparatus, as set forth in claim 7, said manufacturing facility producing at least one type of product, and wherein said surplus feasibility constraint applying means further comprises:
means for computing expected surplus per product type in response to said theoretical production plan; and
means for formulating said surplus feasibility constraint in response to said computed expected surplus.

9. The apparatus, as set forth in claim 1, said manufacturing facility manufactures in units of a fixed number and also in partial units of a number less than said fixed number, wherein said constraint-based model comprises means for applying a constraint which describes the number of partial production units that may be feasibly initiated by said manufacturing facility.

10. The apparatus, as set forth in claim 9, said partial unit feasibility constraint applying means comprises:
means for computing the number of units that are required to be initiated in response to said theoretical production plan;
means for computing the number of partial units that are required to be initiated in response to said theoretical production plan; and
means for formulating said partial unit feasibility constraint in response to said computed number of units and partial units required for said theoretical production plan.

11. The apparatus, as set forth in claim 1, said manufacturing facility producing at least one type of product, and wherein said cost function computing means comprises:
means for computing an expected yield per product type;
means for receiving customer demand;
means for computing a push cost per product type in response to said computed expected yield and said received customer demand;
means for computing a pull cost per product type in response to said computed expected yield and said received customer demand; and
means for computing a cost function of said production plan in response to said computed push and pull costs.

12. The apparatus, as set forth in claim 2, wherein said theoretical production plan generating means comprises:
means for modifying a theoretical plan and generating a plurality of children theoretical plans;
constructing a tree having said theoretical production plan as a root node and said plurality of children theoretical production plans as leaf nodes.

13. The apparatus, as set forth in claim 12, wherein said heuristic searching means further comprises:
means for discarding any leaf node containing a children theoretical production plan which contradict said plurality of applied constraints;
means for selecting from among remaining leaf nodes a theoretical production plan which incurs the least cost; and
means for providing a solution production plan all of whose children production plans contradict said applied constraint.

14. A method for production planning in a manufacturing facility, comprising the steps of:
generating a plurality of theoretical plans;
receiving one of said theoretical production plans, formulating a plurality of constraints in response to said received theoretical plan and applying said formulated constraint thereto;
computing a cost function divided by the addition to work in response to said theoretical production plan; and searching for a feasible production plan among said plurality of theoretical plans, said feasible plan not violating said applied constraint and having the least computed cost function value per addition to work.

15. The method, as set forth in claim 14, wherein said constraint formulating and applying step comprises the step of formulating and applying a production capacity constraint of said manufacturing facility to said theoretical plan.

16. The method, as set forth in claim 15, said manufacturing facility having at least one machine and wherein said capacity constraint formulating step further comprises the steps of:

storing and providing the availability of each machine;

controlling the work-in-process work load;

storing and providing the number of work hours of said manufacturing facility; and

receiving said machine availability, work-in-process and work hours and computing the maximum amount of usage of said machine.

17. The method, as set forth in claim 16, wherein said capacity constraint formulating step comprises the steps of:

storing and providing the amount of usage per machine; and

receiving said machine usage and computing the amount of current usage per machine in response thereto.

18. The method, as set forth in claim 17, said capacity constraint formulating step further comprises the step of formulating said production capacity of said manufacturing facility in response to said maximum usage per machine and said current usage per machine.

19. The method, as set forth in claim 14, wherein said constraint formulating and applying step comprises the step of formulating and applying a constraint which describes the amount of surplus that may be feasibly produced by said manufacturing facility.

20. The method, as set forth in claim 19, said manufacturing facility producing at least one type of product, and wherein said surplus feasibility constraint formulating step further comprises:

computing expected surplus per product type in response to said theoretical production plan; and

formulating said surplus feasibility constraint in response to said computed expected surplus.

21. The method, as set forth in claim 14, said manufacturing facility manufactures in units of a fixed number and also in partial units of a number less than said fixed number, wherein said constraint formulating and applying step comprises the step of formulating and applying a constraint which describes the number of partial production units that may be feasibly initiated by said manufacturing facility.

22. The method, as set forth in claim 21, said partial unit feasibility constraint formulating step comprises the steps of:

computing the number of units that are required to be initiated in response to said theoretical production plan;

computing the number of partial units that are required to be initiated in response to said theoretical production plan; and

formulating said partial unit feasibility constraint in response to said computed number of units and partial units required for said theoretical production plan.

23. The method, as set forth in claim 14, said manufacturing facility producing at least one type of product, and wherein said cost function computing step comprises the steps of:

computing an expected yield per product type;

receiving customer demand;

computing a push cost per product type in response to said computed expected yield and said received customer demand;

computing a pull cost per product type in response to said computed expected yield and said received customer demand; and

computing a cost function of said production plan in response to said computed push and pull costs.

24. The method, as set forth in claim 14, wherein said theoretical production plan generating step comprises the steps of:

modifying a theoretical production plan and generating a plurality of children theoretical production plans;

constructing a tree having said theoretical production plan as a root node and said plurality of children theoretical production plans as leaf nodes.

25. The method, as set forth in claim 14, wherein said searching step further comprises the steps of:

discarding any leaf node containing a children theoretical production plan which contradict said plurality of applied constraints;

selecting from among remaining leaf nodes a theoretical production plan which has the least computed cost function value; and

modifying said selected production plan to generate another plurality of children theoretical production plans;

repeating said above steps until all children production plans from a selected production plan contradict said plurality of constraints; and

providing said last selected production plan as a solution production plan.

FIG. 1

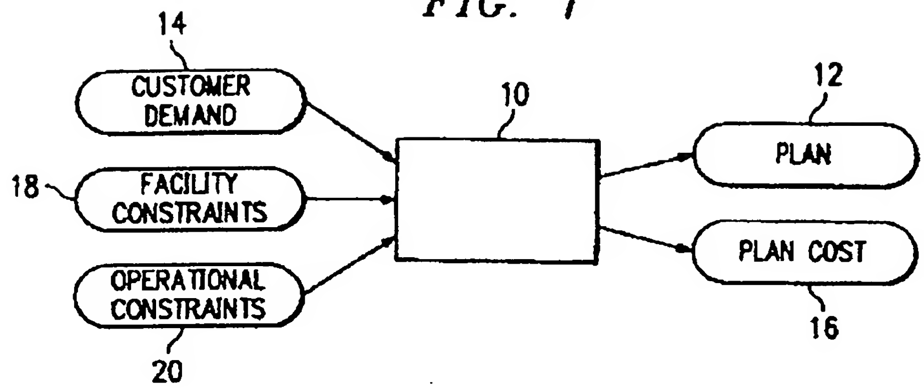
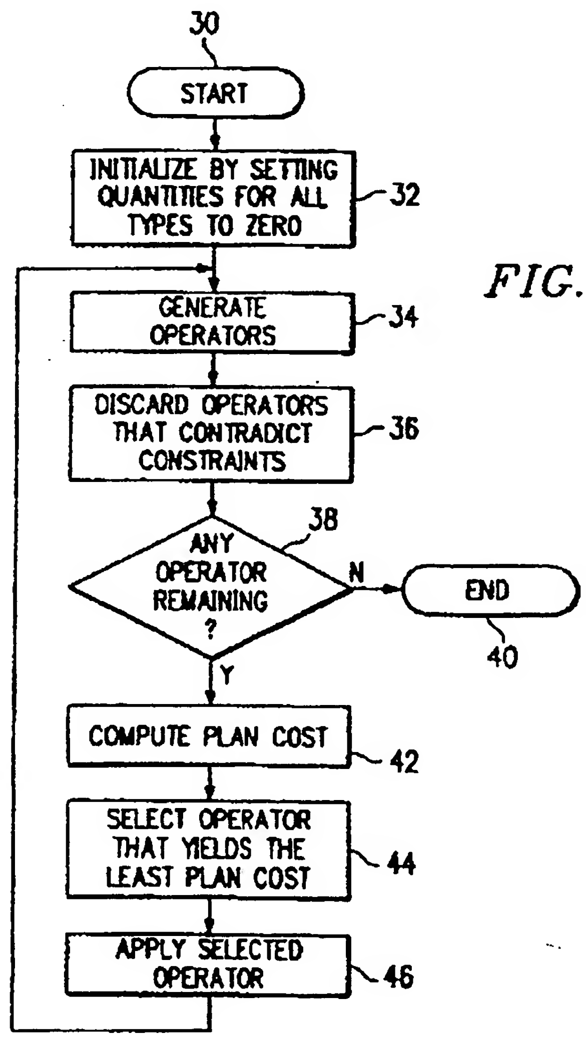
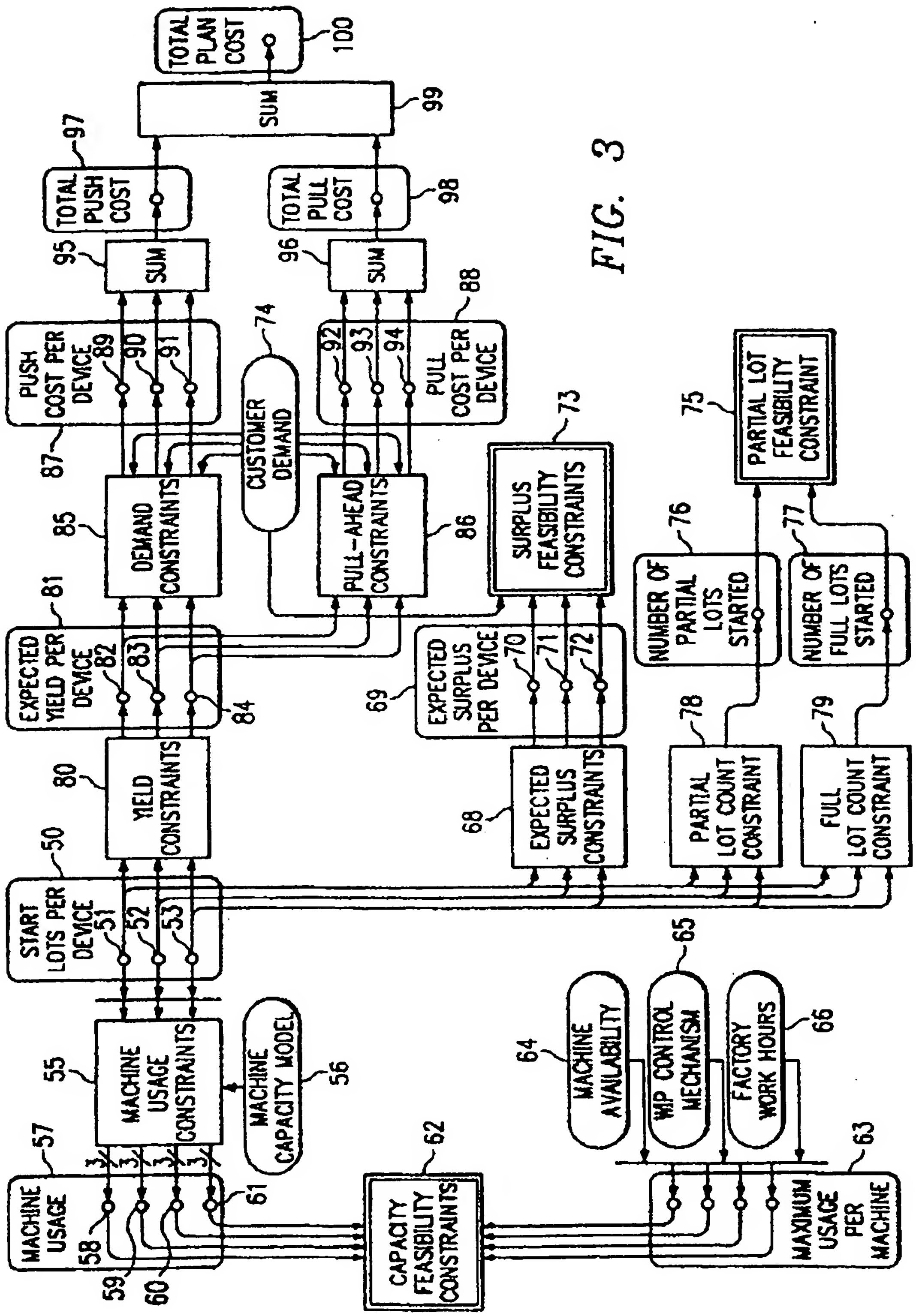

14
CUSTOMER DEMAND
18
FACILITY CONSTRAINTS
OPERATIONAL CONSTRAINTS
20
10
12
PLAN
PLAN COST
16

FIG. 2


30
START
INITIALIZE BY SETTING QUANTITIES FOR ALL TYPES TO ZERO
32
GENERATE OPERATORS
34
DISCARD OPERATORS THAT CONTRADICT CONSTRAINTS
36
38
ANY OPERATOR REMAINING ?
N
END
40
Y
COMPUTE PLAN COST
42
SELECT OPERATOR THAT YIELDS THE LEAST PLAN COST
44
APPLY SELECTED OPERATOR
46



TOTAL PLAN COST
100
SUM
99
TOTAL PUSH COST
97
TOTAL PULL COST
98
SUM
95
SUM
96
PUSH COST PER DEVICE
87
89
90
91
PULL COST PER DEVICE
88
92
93
94
CUSTOMER DEMAND
74
DEMAND CONSTRAINTS
85
PULL-AHEAD CONSTRAINTS
86
SURPLUS FEASIBILITY CONSTRAINTS
73
PARTIAL LOT FEASIBILITY CONSTRAINT
75
NUMBER OF PARTIAL LOTS STARTED
76
NUMBER OF FULL LOTS STARTED
77
EXPECTED YIELD PER DEVICE
81
82
83
84
EXPECTED SURPLUS PER DEVICE
69
70
71
72
YIELD CONSTRAINTS
80
EXPECTED SURPLUS CONSTRAINTS
68
PARTIAL LOT COUNT CONSTRAINT
78
FULL LOT COUNT CONSTRAINT
79
START LOTS PER DEVICE
50
51
52
53
MACHINE USAGE CONSTRAINTS
55
MACHINE CAPACITY MODEL
56
MACHINE AVAILABILITY
64
WIP CONTROL MECHANISM
65
FACTORY WORK HOURS
66
MACHINE USAGE
57
58
59
60
61
3
CAPACITY FEASIBILITY CONSTRAINTS
62
MAXIMUM USAGE PER MACHINE
63

FIG. 3

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number : **0 468 728 A3**

(12) EUROPEAN PATENT APPLICATION

(21) Application number : 91306665.0

(51) Int. Cl.[5] : G06F 15/21

(22) Date of filing : 22.07.91

(30) Priority : 26.07.90 US 558970

(43) Date of publication of application : 29.01.92 Bulletin 92/05

(84) Designated Contracting States : DE FR GB IT NL

(88) Date of deferred publication of search report : 09.02.94 Bulletin 94/06

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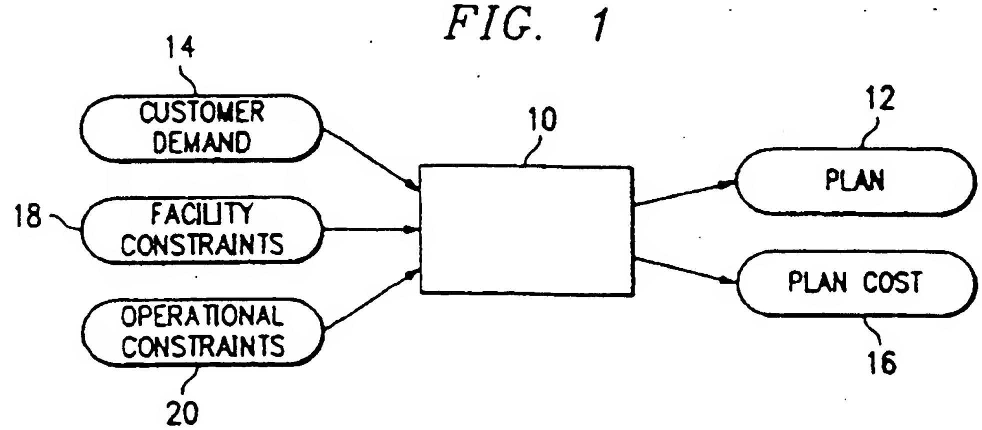
FIG. 1



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EUROPEAN SEARCH REPORT

Application Number
EP 91 30 6665

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
A	COMPUTER. vol. 17, no. 9 , September 1984 , LONG BEACH, CA, US pages 76 - 86 D.A. BOURNE & M.S. FOX 'Autonomous Manufacturing: Automating the Job-Shop' * page 79, right column, line 31 - line 57 * * page 83, right column, line 6 - line 33 *	1-25	G06F15/21
A	PROCEEDINGS OF THE 23RD ANNUAL HAWAII INTERNATIONAL CONFERENCE ON SYSTEM SCIENCES vol. 3 , 2 January 1990 , KAILUA-KONA, HI, US pages 383 - 390 M.L. MANHEIM ET AL. 'A symbiotic DSS for production planning and scheduling: issues and approaches' * page 384, right column, line 34 - line 37 * * page 385, left column, line 7 - line 17 *	1-25	TECHNICAL FIELDS SEARCHED (Int.Cl.5) G06F
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	6 December 1993	Burö, S.P.

CATEGORY OF CITED DOCUMENTS

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1	A	IEEE JOURNAL OF ROBOTICS AND AUTOMATION. vol. 4, no. 4 , August 1988 , NEW YORK, NY, US pages 397 - 402 A. KUSIAK & G. FINKE 'Selection of Process Plans in Automated Manufacturing Systems' * abstract * ---	1-25	
2	A	IEE PROCEEDINGS A. PHYSICAL SCIENCE, MEASUREMENT & INSTRUMENTATION, MANAGEMENT & EDUCATION. vol. 135, no. 8 , November 1988 , STEVENAGE, GB pages 529 - 538 T.J. BARBER & J.T. BOARDMAN 'Knowledge-based project control employing heuristic optimisation' * the whole document * ---	1-25	
4	A	OMEGA vol. 13, no. 3 , 1985 , UK pages 181 - 190 D.B. RINKS 'Marginal Analysis Production Planning' * page 183, right column, line 5 - page 185, left column, line 49 * ---	1-25	TECHNICAL FIELDS SEARCHED (Int.Cl.5)
4	A	36TH NATIONAL MEETING OF THE OPERATIONS RESEARCH SOCIETY OF AMERICA vol. 17, no. 2 , October 1969 , US page B-226 D.R. DENZLER 'A Heuristic Production Lot Scheduling Model' * the whole document * --- -/--	1-25	

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A	EXPERT SYSTEMS vol. 1, no. 1 , July 1984 , US pages 25 - 48 M.S. FOX & S.F. SMITH 'ISIS - a knowledge-based system for factory scheduling' * page 37, left column, line 3 - page 38, left column, line 4 * * page 44, left column, line 11 - right column, line 27 * ---	1-25	
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